or taking Chappuis and Harker's value for the boiling point, which is 0·74° higher, we obtain for ∂ 1·54.

Conclusion.—As might be expected, it is possible to apply the parabolic formula of Callendar and Griffiths to the recalculation of the differences between the platinum scale of temperature and the scale of the gas thermometer, though the range through which it is applicable, and the value of the constant ∂, precludes the possibility of employing it except for interpolation. A standard scale of temperature, based on Callendar's three fixed points, using standard wire, and taking 1·5 for the value of ∂, would obviously lead to absurd results at low temperatures; and the converse may be said of our own observations. To sum the matter up, we will tabulate the results that have been referred to in this paper.

Nature of gas thermometer.	Observer.	∂.
Constant pressure air (0° to 444°)	Callendar and Griffiths	1·50
Constant volume nitrogen (−23° to 445°)	Chappuis and Harker	1·54
Constant volume nitrogen standardised by constant pressure air at 444° (500° to 1000°)	Harker	1·51—1·49
Constant volume hydrogen (−190° to 34°)	Travers and Gwyer	1·90

"The Arc Spectrum of Scandium and its Relation to Celestial Spectra."

By Sir NORMAN LOCKYER, K.C.B., LL.D., Sc.D. F.R.S., and F. E. BAXANDALL, A.R.C.Sc. Received January 3, —Read February 9, 1905.

Very little has been published regarding the spectrum of this rare element. The records of Thalen,* and Exner and Haschek,† are the only ones previously given, the former observer confining his attention to the spark spectrum, whereas Exner and Haschek have recorded the lines under both arc and spark conditions. In the latter lists, however, no lines are given in the region less refrangible than λ 4744·0. Rowland, in his "Tables of Solar Wave-lengths," certainly ascribes a small number of solar lines to scandium, but, of course, no indication is there given as to the relation of these lines to others which occur in the scandium spectrum, either in regard to number or intensity. In connection with the work at Kensington on stellar and other celestial spectra, it has been found that in some types of spectra scandium is conspicuously represented by some of its lines, in fact,

* 'Öfversigt af Kongl. Vetensk. Akad. Forhandl.,' vol. 38, No. 6, p. 13.

† 'Wellenlängen-Tabellen für Spektralanalytische Untersuchungen auf Grund der Ultravioletten Funkenspektren und Bogenspektren der Elemente,' Leipzig und Wien, Franz-Deuticke, 1902.

amongst the rarer elements it apparently stands by itself from this point of view. This prominence of scandium lines in some stellar spectra, and particularly in the chromospheric spectrum, makes it desirable to give as complete a record of the lines as possible, and also to analyse them in relation to their appearance or non-appearance in extra-terrestrial spectra.

Some time ago Sir William Crookes was good enough to send a sample of scandium oxalate, and very good photographs of the arc spectrum have been obtained with a larger Rowland concave grating, having a ruled surface of $5\frac{3}{4} \times 2$ inches ($14\frac{1}{2} \times 5$ cm.), and a radius of 21 feet 6 inches. The scale of the photographs is such that the distance between K and D is $30\frac{1}{4}$ inches, or 77 cm. This is equivalent to 2·6 tenth-metres per millimetre. The scandium oxalate was admittedly impure, and for the purpose of eliminating lines due to impurities, the spectrum has been directly compared with the spectra of all the chemical elements available at Kensington, which were photographed under identical instrumental conditions. The chief sources of impurity were found to be cerium, thorium and ytterbium. The lines of the first two elements were easily eliminated by comparison with the Kensington photographs of their respective arc spectra. In the case of ytterbium it was a more difficult matter, as this is one of the elements not investigated at Kensington. The elimination of its lines has, however, been accomplished as far as possible, by ascertaining whether there were lines in the scandium photograph in the position of the stronger lines of ytterbium as recorded by Thalen,* and Exner and Haschek.† If such were found to be the case, and the intensity in the scandium photographs such that the line was thought to be due to ytterbium, it was discarded from the list of scandium lines.

The fiducial lines used for the reduction of wave-lengths were the H and K lines of calcium (which occur as impurity lines in the scandium spectrum), and Rowland's solar-scandium lines 3907·62, 4020·55, 4082·59, 4247·00, 4314·25, 4400·56, 4670·59, 5672·05. The coincidence of these lines was first confirmed by a direct comparison of the Kensington photographs of the solar and scandium spectra. In addition to the foregoing, well-marked scandium lines were found to be exactly coincident with the isolated solar lines 5031·20, 5239·99, and 5527·03, for which Rowland had given no origin. The solar wave-lengths of these were adopted and used in the reduction of the wave-lengths of the remaining lines.

The table at the end of the paper gives the residuum of lines after

* 'Öfversigt k. Vetensk. Akad. Forhandl.' (1881).

† Wellenlängen Tabellen für Spektralanalytische Untersuchungen auf Grund der Ultravioletten Bogenspektren der Elemente,' Leipzig und Wien, Franz-Deuticke, 1904.

the elimination of those due to other metals. There can be little doubt that the majority of the lines, except, perhaps, some of the very lowest intensity, really belong to scandium. Exner and Haschek's wave-lengths and intensities of the scandium arc lines are given for comparison.

Scandium Lines in the Solar Spectrum.

Rowland, in his "Tables of Solar Wave-lengths," ascribes a small number of lines to scandium, but a comparison of the Kensington photographs of the arc spectrum of this element with the solar spectrum shows that in addition to these there are other solar lines nearly certainly due to the same element. The table gives the solar lines which, by a careful comparison of the metallic and solar spectra, have been considered to correspond, without any doubt, with scandium lines. In addition to these, there is a considerable number which agree closely in position with weak solar lines, but of their identity there is, perhaps, some doubt. In some cases the solar lines are so weak that it is impossible to establish their identity with scandium lines by direct comparison of the two spectra, the only guide being the close agreement in wave-length, and the relative intensity of the metallic and solar lines. In other cases it is doubtful whether the metallic lines are strong enough to account for the solar lines. In the table these lines are denoted by an asterisk, and must be accepted only provisionally as "possible" scandium-solar lines.

The following analysis of the scandium lines, with reference to their intensities, and their appearance or non-appearance in the solar spectrum, will be of interest.

Intensity (Sc. arc lines).	Total number of Sc. lines.	Number undoubtedly represented in solar spectrum.	Number possibly represented in solar spectrum.	Number apparently absent from solar spectrum.
10	4	4	—	—
9	3	3	—	—
8	7	6	1	—
7	4	3	1	—
6	5	2	1	2
5	7	3	4	—
4	15	6	3	6
3	21	—	5	16
2	28	—	2	26
1	16	—	—	16

It will be seen that of the 23 lines of intensity 6 or greater, 18 occur in the solar spectrum, three others are doubtfully present, while

two appear to be lacking. Of the lines below intensity 6, the great majority are missing from the Fraunhoferic spectrum.

Scandium Lines and the Chromospheric Spectrum.

The scandium lines which occur in the chromospheric spectrum, though not so numerous as those in the solar spectrum, are of considerably greater prominence. The strongest line of scandium at λ 4247·00 is very well developed in the chromosphere, and is, as far as the metallic lines are concerned, inferior only to the lines of strontium and calcium. Although all the scandium lines represented in the chromosphere have high intensities in the scandium arc spectrum, there are a few others of equal prominence in the metallic spectrum which are either lacking or occur only as quite insignificant lines in the chromospheric spectrum.

Chromospheric Lines probably due either wholly or partially to Scandium.

Chromospheric line.		Scandium line.			Remarks.
λ.	Intensity. Max. 10.	λ.	Intensity. Arc. Max. 10.	Intensity. Spark. Max. 10.	
4247·0	7	4247·00	10	10	Due solely to scandium.
4314·0	2	4314·25	9	8	,, ,,
4321·2	5	4320·90	9	6	Probably partially due to *p*Ti 4321·20.
4374·9	7	4374·65	8	6	Probably partially due to *p*Ti 4374·90.
4399·9	5—6	4400·56	8	5	Probably partially due to *p*Ti 4399·94.
4670·8	3—4	4670·59	7	4	Due solely to scandium.
5031·2	2	5031·20	8	3	,, ,,
5527·6	6	5527·03	10	7	This chromospheric line is broad and is probably composed of the scandium line and the strong Mg spark line λ 5528·64.

Scandium Lines in Sun-Spot Spectra.

Between F and D, the region over which the Kensington observations of sun-spot spectra extend, there are nine solar lines which have been found to be due to scandium, either wholly or partially. Of these, five

occur amongst the most widened lines observed during the last 24 years. Four of them, however, have only been recorded a few times. The remaining one, λ 5672·047, is a very persistent widened line and is nearly always greatly affected. It is, of course, quite possible that the solar line in question, although weak, may be a compound one, and that an additional chemical element is involved in its formation. No origin other than scandium has been suggested by Rowland, and no alternative origin has been found for it by reference to Kensington spectra of metals. It must, therefore, be accepted provisionally as being really due to scandium.

Scandium Lines in Stellar Spectra.

It is quite probable that, as the stronger scandium lines occur in the solar spectrum, they also appear in the spectra of stars resembling the sun, such as those of the Aldebarian and Arcturian types. The closeness of the lines in these stars with the dispersion usually employed on stellar spectra makes it difficult to establish definitely whether the scandium lines are really present. At the next higher stage (Polarian, *e.g.*, γ Cygni) those scandium lines previously given as occurring in the chromospheric spectrum—at least, those in the ordinary photographic region, say λ 3900 to λ 4700—occur as well marked lines, as has been shown in a previous paper.*

At the next higher stage Cygnian (α Cygni) the only line which can with certainty be ascribed to scandium is that at λ 4247·00, corresponding to the strongest line of the element. Its stellar intensity, has, however, decreased considerably from that of the Polarian stage. At the higher stages represented successively by Rigelian (β Orionis), Taurian (ζ Tauri), Crucian (γ Orionis), and Alnitamian (ζ Orionis) types scandium lines are entirely lacking.

The photographs of the metallic spectra involved in the discussion were taken by Mr. C. P. Butler, A.R.C.Sc.

* 'Phil. Trans.,' A, vol. 201, p. 205.

Arc Lines of Scandium.

* = Doubtfully identical with solar lines.

Kensington.		Exner and Haschek.		Corresponding solar lines.		Rowland's origin for solar lines.
λ.	Int. Max. 10.	λ.	Int. Max. 50.	λ.	Int.	
3907·62	10	3907·69	30	3907·62	3	Sc–Fe
11·94	10	12·03	30	11·96	2	Sc
		15·09	1			
		18·36	1			
		23·64	1			
		33·59†	6			
		52·43	1			
		89·18	1			
* 96·75	5	96·79	15	96·68	00	Sc
4014·66	3	4014·68	6			
20·55	8	20·60	20	4020·55	1	Sc
		23·36	1			
23·88	8	23·88	30	23·83	2	Sc
		31·51	2			
34·35	2					
36·98	1					
43·97	2					
46·64	2					
47·97	4—5	47·98	10	47·96	0	—
		50·09	2			
		52·00	1			
* 54·68	3	54·71	10	54·71	00	Sc
		56·72	3			
		67·15	2			
		75·13	2			
		78·70	2			
82·59	6	82·60	15	82·59	3	Fe–Sc–Ti
		86·15	1			
86·67	2—3	86·80	3			
87·26	1	87·28	3			
* 94·85	2—3	95·03	1	94·85	0	—
4106·02	2—3					
33·10	2	4133·10	4			
* 40·42	2—3	40·42	5	4140·40	0	—
41·78	1					
52·50	3	52·51	8			
62·85	1					
63·77	1					
65·38	2—3	65·39	8			
71·47	1—2					
71·98	2—3	71·92	2			
		4218·43	1			
		19·90	1			
4224·32	1					
		25·76	1			
		32·13	1			

† Possibly masked in Kensington photograph by K line of Ca.

Arc Lines of Scandium—*continued.*

Kensington.		Exner and Haschek.		Corresponding solar lines.		Rowland's origin for solar lines.
λ.	Int. Max. 10.	λ.	Int. Max. 50.	λ.	Int.	
		4233·83	2			
		37·96	1			
4238·25	2	38·21	3			
		39·72	1			
		46·27	1			
47·00	10	47·02	50	4247·00	5	Sc
		51·22	1			
		83·71	1			
		86·71	1			
* 94·91	4—5	94·94	5	94.94	2	Zr
4305·83	4—5	4305·89	8	4305·87	2	—
14·25	9	14·31	30	14·25	3	Sc
20·90	9	20·98	20	20·91	3	Sc
25·15	8	25·28	20	25·15	4	Sc
54·74	3—4	54·79	3	54·78	1	—
		58·85	1			
		59·25	1			
74·65	8	74·69	20	74·63	3	Sc
84·99	4	84·98	3	84·99	0	Sc
		89·76	1			
4400·56	8	4400·63	20	4400·56	3	Sc
15·72	7	15·78	20	15·72	3	—
* 20·82	1—2	20·84	1	20·83	00	—
* 31·56	2—3	31·52	2	31·53	0	—
		4542·74	1			
		44·86	1			
		57·45	1			
*4563·40	2	—	—	4563·41	00	—
		74·20	2			
		4604·88	1			
4670·59	7	70·59	5	4670·59	2	Sc
		4709·53	1			
		29·43	2			
*4729·39	3	29·40	1	4729·38	0000	—
* 34·31	3—4	34·31	3	34·28	1	Fe ?
37·88	4	37·86	3			
* 41·24	5	41·23	4	41·26	1	Fe ?
* 44·04	6	44·01	5	44·01	000	—
		Exner and Haschek's record stops here.				
4820·52	2—3					
37·27	2—3					
4937·29	2—3					
54·12	1—2					
80·49	1					
87·26	1—2					
92·06	1—2					
5009·68	2					
31·20	8	—	—	5031·20	3	—
64·35	2					
70·34	3—4					

Arc Lines of Scandium—*continued.*

Kensington.		Exner and Haschek.		Corresponding solar lines.		Rowland's origin for solar lines.
λ.	Int. Max. 10.	λ.	Int. Max. 50.	λ.	Int.	
5075 ·85	1—2					
79 ·79	1					
81 ·68	6					
83 ·77	5					
* 85 ·64	4	—	—	5085 ·67	0	—
87 ·06	3					
87 ·18	2					
89 ·95	2					
96 ·81	2					
99 ·28	3—4					
5101 ·21	2					
04 ·43	1					
05 ·60	2—3					
09 ·09	1					
10 ·85	<1					
12 ·87	1					
16 ·73	2					
21 ·60	1					
31 ·14	<1					
47 ·08	2					
48 ·28	2					
5239 ·99	5—6	—	—	5239 ·99	1	—
58 ·46	2—3					
69 ·65	1—2					
85 ·88	2					
5307 ·83	1					
18 ·41	2					
25 ·14	2					
28 ·05	1					
49 ·32	3					
56 ·14	3—4					
58 ·69	2—3					
89 ·89	1—2					
92 ·12	3					
5478 ·66	2					
82 ·18	4					
* 84 ·81	3—4	—	—	5484 ·85	000	—
5514 ·40	4					
* 20 ·70	4—5	—	—	5520 ·73	00	—
27 ·03	10	—	—	27 ·03	3	—
91 ·44	2					
5658 ·10	7	—	—	5658 ·10	2	Y
58 ·56	3—4	—	—	58 ·56	0	—
67 ·40	3—4	—	—	67 ·37	0	—
69 ·25	4	—	—	69 ·26	1	—
72·05	9	—	—	72 ·05	0	Sc
84 ·44	4	—	—	84 ·42	1	—
* 87 ·07	8	—	—	87 ·06	000	—
*5700 ·38	7	—	—	5700 ·40	00	—
11 ·98	6					
17 ·54	3					